<Advanced Research Center for Beam Science>Laser Matter Interaction Science

Advanced Research Center for Beam Science – Laser Matter Interaction Science –

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Prof
SAKABE, Shuji
(D Eng)

Assoc Prof
HASHIDA, Masaki
(D Eng)

Assist Prof
INOUE, Shunsuke
(D Sc)

PD
NAKAMIYA, Yoshihide
(D Sc)

PD
MIYASAKA, Yasuhiro
(D Sc)

Lect (pt)

TOKITA, Shigeki (D Eng)   Institute of Laser Engineering, Osaka University

Students

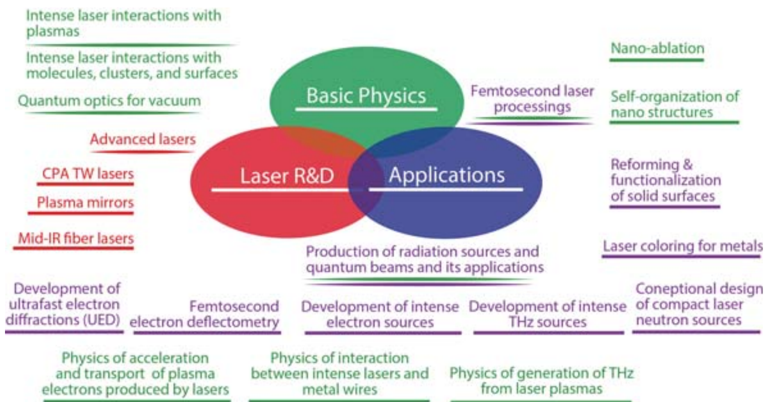
MORI, Kazuaki (D1)
NAKASHIMA, Yuto (M2)
MAEDA, Kazuya (M2)
TERAMOTO, Kensuke (M2)
NISHII, Takaya (M2)
WATANABE, Kota (M1)

Scope of Research

The interaction of femtosecond laser pulses with matters involves interesting physics, which does not appear in that of nanosecond laser pulses. Investigating the interaction physics, potential of intense femtosecond lasers for new applications is being developed (such as laser produced radiations and laser processing). Ultra-intense lasers can produce intense radiations (electrons, ions, THz, and so on), which can be expected as the next-generation radiation sources. Ultra-short lasers are available to process any matters without thermal dissociation. The femtosecond laser processing is also the next-generation laser processing. In our laboratory ultra intense femtosecond laser named T^6-laser is equipped, and the physics of intense laser matter interactions and its applications are researched.

KEYWORDS

Intense Laser Science
Laser Plasma Radiations (electrons, ions, and THz)
Ultrafast Electron Diffraction (UED)
Laser Nano-ablation Physics
Femtosecond Laser Processing



Selected Publications

Gemini, L.; Hashida, M.; Shimizu, M.; Miyasaka, Y.; Inoue, S.; Tokita S.; Limpouch, J.; Mocek T.; Sakabe, S., Periodic Nanostructures Self-formed on Silicon and Silicon Carbide by Femtosecond Laser Irradiation, *Appl. Phys. A*, **117,** 49-54 (2014).

Hashida, M.; Gemini, L.; Nishii, T.; Miyasaka, Y.; Sakagami, H.; Shimizu, M.; Inoue, S.; Limpouch, J.; Mocek T.; Sakabe S., Periodic Grating Structures on Metal Self-organized by Double-pulse Irradiation, *J. Laser Micro/Nanoeng*., (in press).

Nakajima, H.; Tokita, S.; Inoue, S.; Hashida, M.; Sakabe, S., Divergence-Free Transport of Laser-Produced Fast Electrons Along a Meter-Long Wire Target, *Phys. Rev. Lett*., **110,** 155001 (2013).

Hashida M.; Ikuta Y.; Miyasaka Y.; Tokita S.; Sakabe S., Simple Formula for the Interspaces of Periodic Grating Structures Self-organized on Metal Surfaces by Femtosecond Laser Ablation, *Appl. Phys. Lett*., **102,** 174106 (2013).

Jahangiri, F.; Hashida, M.; Tokita, S.; Nagashima, T.; Hangyo, M.; Sakabe, S., Enhancing the Energy of Terahertz Radiation from Plasma Produced by Intense Femtosecond Laser Pulses, *Appl. Phys. Lett*., **102,** 191106 (2013).

Transient Changes in Electric Fields Induced by Interaction of Ultra-intense Laser Pulses with Insulator/Metal Foils: Sustainable Fields Spanning Several Millimeters

The generation and transport of fast electrons during and after the interaction of ultra-short high-intensity laser pulses with a target play a crucial role in the consequent emission of energetic radiation, such as ions, X-rays, gamma rays, and terahertz waves. Studies have demonstrated that the dynamics of fast electrons is influenced by the shape and material of the laser-irradiated target. Many shapes and materials for irradiation targets have been studied in order to achieve better control over the dynamics of fast electrons. Most recently, some reports have indicated that the shape and material of the target outside the laser-induced plasma can influence the dynamics of fast electrons, and consequently the characteristics of other types of radiation. Therefore, it is important to observe and understand the dynamics of fast electrons, and the electromagnetic fields that they induce, over a large region (on the order of several millimeters) outside the laser-irradiated region for various materials. This could aid the development of efficient laser-induced plasma radiation sources for many attractive applications, including fast ignition for inertial confinement fusion, ultrafast electron diffraction measurements, time-resolved X-ray probes, laser-driven nuclear physics, and tumor therapy using ion beams.

We report measurements of electromagnetic fields at a distance of several millimeters from the position irradiated with an intense laser for three types of targets: insulating foil, conductive foil, and insulating foil onto which a metal disk was deposited. The measurements were performed by femtosecond electron deflectometry. We observed distinct differences in the direction and temporal evolution of the fields depending on the target material. We also measured the electromagnetic fields for different laser intensities (1.3×10^{18} and 8.2×10^{18} W/cm^2) and found that the transport of fast electrons also depended on laser intensity for each target material.

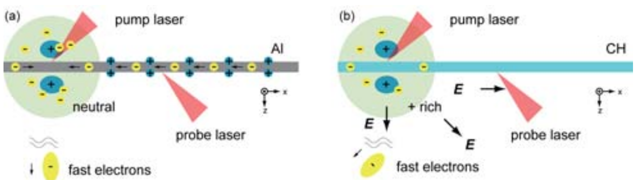


Figure 1. Schematic illustrations of the reduction of electric field along the target surface due to the influx of the surrounding free electrons (a) and the generation of the electric fields by the large resistivity of the insulating target (b).

Periodic Grating Structures on Metal Self-organized by Double-pulse Irradiation

The formation of periodic grating structures has been demonstrated on a titanium surface irradiated by a double-pulse beam with a time delay of 160 fs. The first-pulse fluence F_{PP} was varied and always kept below the threshold F_{TH} = 60 mJ/cm^2 for forming periodic grating structures on Ti and the delayed pulse fluence F_{LP} was kept above F_{TH}. The grating structure interspaces were $0.5\lambda_L$ to $0.85\lambda_L$ and decreased with F_{PP} for all values of F_{LP}. This tendency suggests that variation in surface plasma density, which is associated with the fluence of the first pulse, led to variation of the grating interspaces. We found that the interspaces produced by double-pulse irradiation agreed relatively well with those produced by single-pulse irradiation and those predicted by a parametric decay model. To visualize the surface plasma wave induced by the femtosecond laser, two-dimensional particle-in-cell simulation was conducted for a pre-formed plasma on a metal. The simulation results suggest that the preformed plasma density led to the variation in the grating interspaces.

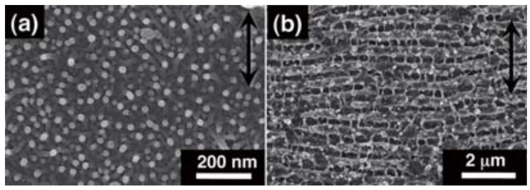


Figure 2. SEM images of surface structures on titanium produced by (a) 1 pulse and (b) 25 pulses, for double-pulse irradiation with a time delay of 160 fs. The laser fluence of the first pulse was F_{PP} = 45 mJ/cm^2 and that of the delayed pulse was F_{LP} = 100 mJ/cm^2. Black arrows indicate the laser polarization direction for the double-pulse beam.

Intense THz Emission from Laser Produced Cluster Plasma

Intense terahertz (THz) radiations have a possibility of being used in great variety of applications. To generate intense THz waves, the schemes using nonlinear crystal or photoconductive antenna have been studied. However incident laser energy is limited by the damage threshold of the crystal. Laser plasmas have benefit of damage-free as a THz-wave source. Therefore THz radiation from plasmas produced by intense femtosecond laser pulses has been studied to explore the potential of future intense THz sources. We have proposed the cluster plasma as the target, which combines both the advantages of the solid and the gas plasmas. The properties of generated THz waves have been measured for various laser pulse duration. It has been found that the energy and spectrum of THz pulse generating from argon cluster plasmas depend on laser pulse duration.